PFAS Management

Current State of Treatment Technology

Presented By: Phil Farina BS, BA, MS, MBA
Midwest Business Development Manager



CLEAR CREEK SYSTEMS, INC.

Agenda

- Introduction of Clear Creek Systems
- Where do we find PFAS contamination
- Methodology
- Current PFAs treatments
- Technology driven solutions with client focus

Clear Creek Systems

- Founded in 1994 and currently ~60 employees
- Nationwide service capability
- Full-service technology solutions provider
- Large- and small-scale projects (5 – 20,000gpm)
- Design, build, install, operate; purchase, rent
- Access to all treatment technologies
- Solutions focused

“A strategic partnership to developed to provide engineered solutions to solve the most complex water and solids problems”

Introduction of Clear Creek Systems

Markets

- Groundwater Remediation
- Construction dewatering / industrial stormwater
- Landfill leachate management
- Dredging support / solids separations
- CCR Closure
- **PFAs remediation**

Experience

- Suspended solids
- PCBs
- Oil and Grease
- Metals (Zinc, Copper, Chromium, Arsenic, Mercury, Lithium, Selenium etc.)
- Chemical additions (pH, flocculants, coagulants, etc.)
- Passive /active media filtration
- **PFAs**

Polyfluoroalkyl Substances (PFAS)

The Forever Chemical does not have to be a Forever Problem

Where do we find PFAS

- Airports
- Industrial sites
- Well Waters
- Landfills
- Transfer stations
- Material recovery facilities
- Leachate treatment plants
- POTW’s
- Paper production
- Semiconductor industry
- Cogen facilities
- Recycling centers
- Groundwater remediation projects
- Construction dewatering
- Lakes, streams, or running waters

EVERYWHERE YOU LOOK

Wholistic Approach

- **Consider the water and its ultimate use**
  - Ground water, well water, pond water, PFAS bloom, Municipal, Industrial, Landfill Leachate, Storm Water
  - Drinking water, NPDES permit, outflow to river, WWT system, irrigation
  - Waste stream created by treatment
- **Analyze the water**
  - Include TSS, pH, PFAS speciation, Metals, Organics, VOC etc.
  - How are you delivering the water to the system
- **Understand the treatment requirements based on permit limits**
  - PFAS limit (70 PPT down to 7 PPT)
  - Other concerns such as TSS, pH, metals, VOC, organics, nitrates, sulfates etc.
- **Equipment selection**
  - Permanent or Temporary
  - Flow rate
  - Regeneration or replacement

Pretreatment Technologies Employed

- Filtration
  - Bag filter
  - Cartridge filter
  - Sand filter
  - Multi-media filter
  - Oil water separation
  - Coagulation/ Flocculation/Settling
- Chemical Experience
  - Polymers
  - Flocculants
  - Coagulants
  - pH adjustment

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Pretreatment Technologies Employed

- Media
  - Carbon
  - Clay
  - Ion Exchange
  - Blends
- Metals
  - Resins
  - Zero-Valent Iron
  - Electrocoagulation
  - Activated Alumina
  - Reverse Osmosis

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Common PFA Treatments

- **Carbon**
  - Well known, significant history
  - More general in application
  - Virgin or reactivated carbon
  - Mid-range and longer chain preference
  - Renewable carbon sources, Mined carbon (bituminous)
- **Organoclay**
  - Used in conjunction with other media
  - Can be blended to improve performance
  - Can remove other contaminants such as oils, heavy metals
- **Ion exchange resins (IX)**
  - Newer technology
  - Can be used with or replace carbon
  - Man-made polymers - PFAS specific, designer system
  - Long and short chain PFAS preference
  - Can get to lower target levels

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Carbon

Positives

- Low cost
- Easily obtained
- Variety of packages: bags, super-sacks, bulk
- Easy disposal via incineration or regeneration
- Excellent for short term projects
- High Flow capability

Negatives

- Exhausts quickly, frequent change out
- Difficult to get to 7 PPT in some applications
- Easily clogged
- Allows some PFAS to pass through
- Regenerated carbon may be only 80% effective
- Regenerated GAC can’t be used in drinking water applications
- Potential high total use cost

Carbon

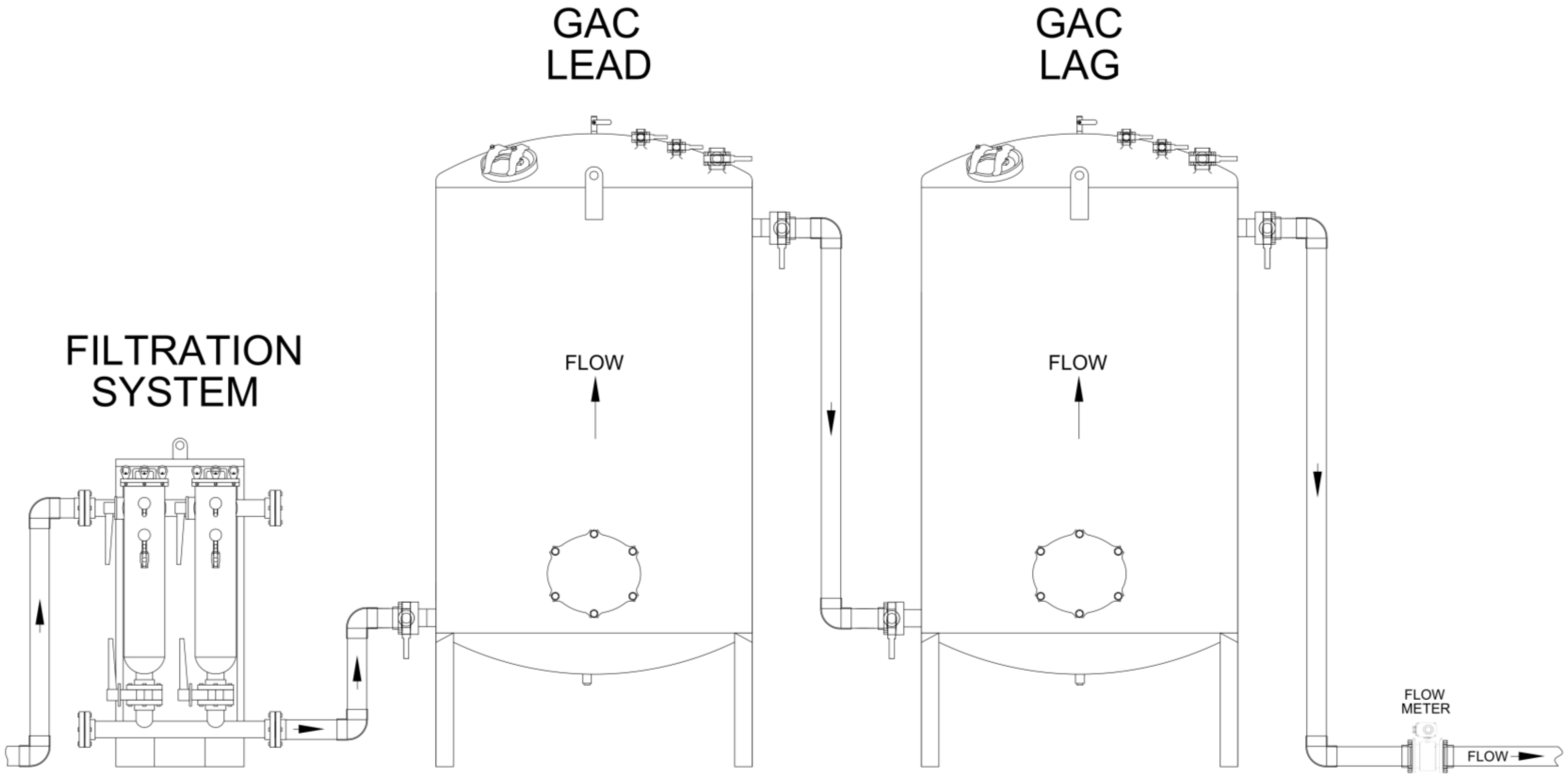
Granular Activated Carbon

- Many forms from Coconut Shell to Bituminous sources each has different capacity for PFAS
- May require large vessels for larger flow rates
- Lead/Lag configuration
- 10 Min EBCT
- Removes all Organics; may interfere with PFAS uptake
- Adsorption into pore structure allows for desorption back into the stream
- Dissolved Organic Carbon (DOC) negatively impacts PFAS uptake

Granular Activated Carbon

- Preference given to Long Chain molecules and mid-range polymers
- Removes branched PFAS better than linear chain molecules
- Preference given to hydrophobic PFAS molecules
- Multi-faceted streams are therefore problematic for carbon systems
- Removes PFAS quickly: however exhaustion curve shows carbon changeout prematurely as carbon continues to remove PFAS but not to required treatment levels
- Capacity limited to reactive site availability
- Effective use 30,000 BV

Carbon


GAC
LEAD
GAC
LAG
FILTRATION
SYSTEM
FLOW
FLOW
FLOW
METER
FLOW

Organoclay

Positives

- Bentonite or Zeolite clay sources
- Renewable mined sources
- Blended to specific need
- Removes PFOA, PFOS, FTCA, FTSA, FTOH, PFCA
- Long and short chain species
- Removes branched species effectively
- High working capacity use less volume than carbon
- Ion exchange and adsorption mechanism

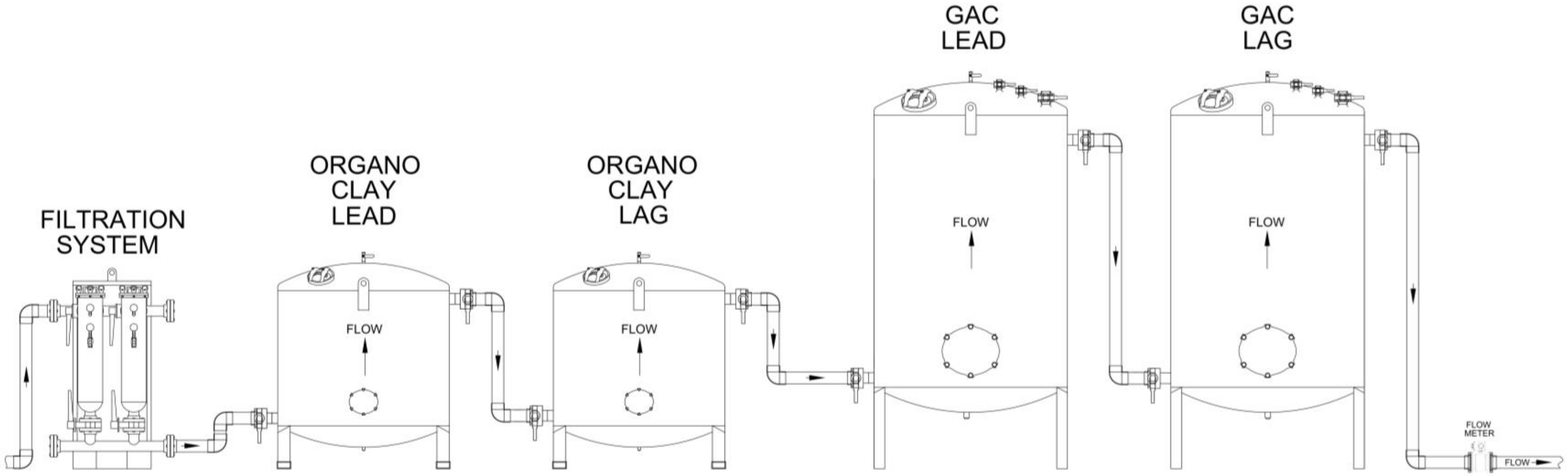
Negatives

- Hydrophilic surface, requires modification
- Prefiltration suggested to prevent “clogging”

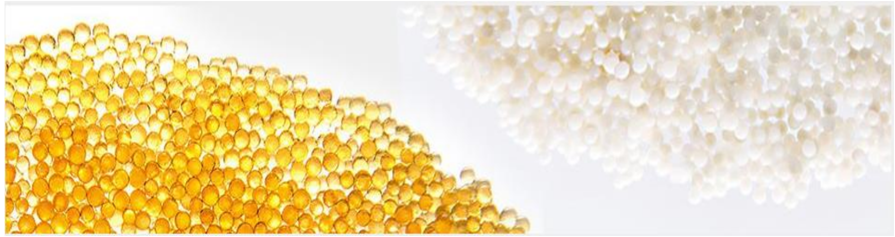
Organoclay

- **Organoclay**
  - Frequently used in conjunction with carbon
  - Can be blended with carbon to reduce footprint
  - Can remove oils
  - Can be modified to remove some organics
  - Specialty clays can remove some heavy metals
  - Can hold a higher capacity of PFAS before exhaustion
  - 5 Min EBCT
  - >50,000 BV typical performance

Organoclay


FILTRATION SYSTEM
ORGANO CLAY LEAD
ORGANO CLAY LAG
GAC LEAD
GAC LAG
FLOW
FLOW
FLOW
FLOW
FLOW METER
FLOW

Ion Exchange



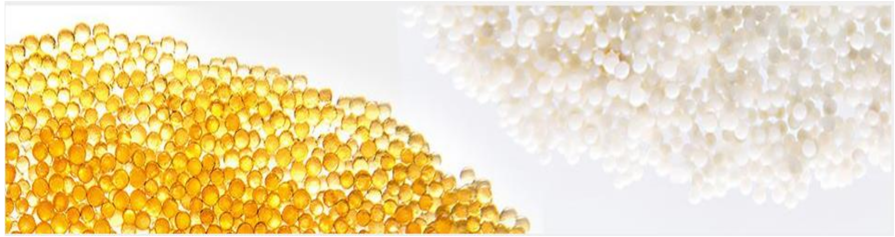
Positives

- Manmade specifically for PFAS removal
- Ion exchange positively charged sites
- Adsorption mechanism
- Wide variety of resins available
- Very high holding capacity
- Can reach non detect levels
- Less frequent media change out
- Regeneration capabilities for some resins
- Exhausted resin approved as a fuel in cement manufacture

Negatives

- Inorganics affects performance
- Somewhat limited availability
- SO4, NO3, HCO3, Cl, TO impact resin performance
- TSS and organic matter may foul resin

Ion Exchange



Ion Exchange Resin

- Filtration prior to resin vessel is recommended
- Must know the speciation to select proper resin
- Prefers Sulfonic Acids (PFOS) and longer chain species
- Also effective with some short chain species
- Ion exchange and adsorption mechanism
- Lead / Lag configuration
- High holding capacity with quick reaction time
- 2.5 min EBCT; very fast kinetics;
- May last 1 – 3 years
- >100,000 BV typical performance

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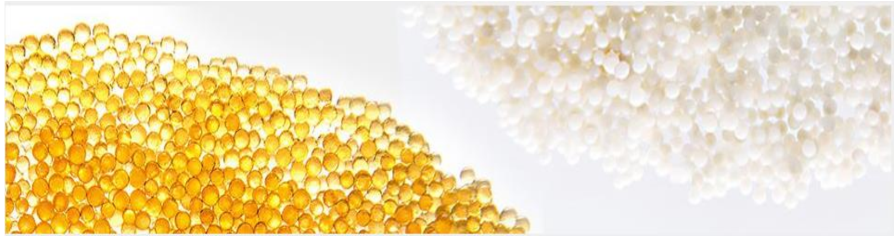
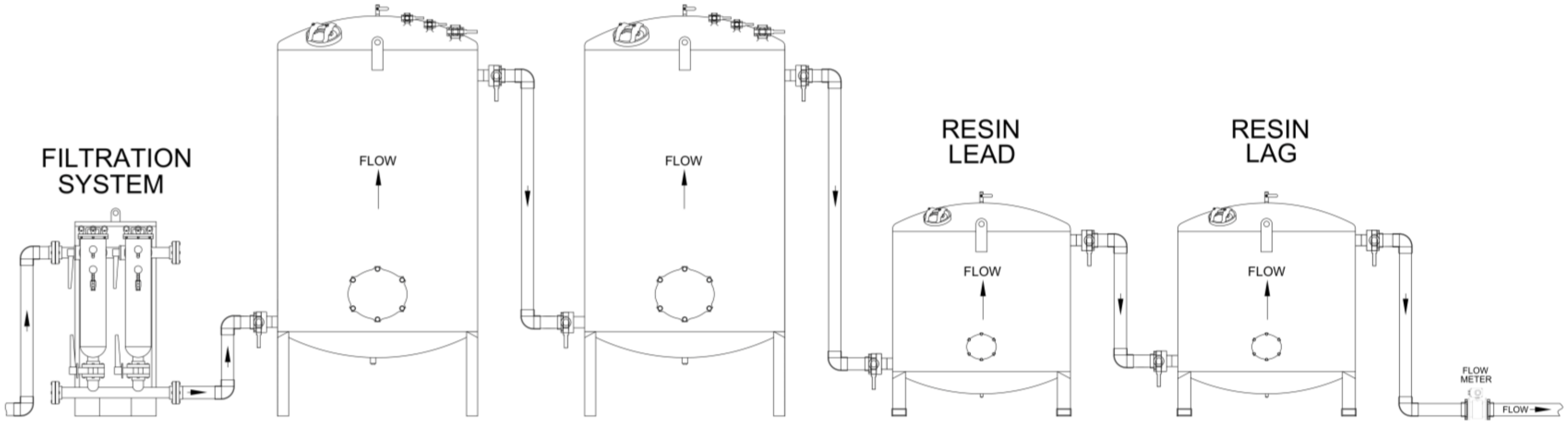
Ion Exchange





Other Technologies

- **Nano-Filtration**
  - Used in combination with media absorption
  - Point of use systems in house drinking water systems
- **Electro-Coagulation**
  - Electrical cleavage of the Fluorine bond
- **PFAS destruction technology**
  - Chemical cleavage of the Fluorine bonds
- **R/O membrane**
  - May be used in combination with adsorption for drinking water applications
  - High and low pressure systems
- **Biological treatment**
  - PFAS is a man-made non-naturally occurring substance
  - Not subject to biological treatment
  - Looking for the magic BUG

Wholistic Approach

- Understand the water chemistry
- Define the specific outcomes of the project
- Design a treatment system for your specific needs

“Clear Creek Systems / Yukon Technology Are Your Partners in PFAS Remediation Management”

Clear Creek Systems

- Individually engineered solutions for PFAS applications:
  - Customized, fabricated, self-contained systems
  - Permanent or temporary system designs
- Field services:
  - Installation
  - Operation
  - Maintenance
  - Upgradeability / optimization evaluation
- Systems available for purchase or rental

Contact Information

Clear Creek Systems

Phil Farina BS, BA, MS, MBA
Midwest Business Development Manager
pfarina@clearcreeksystems.com
419-346-8848